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[Title of the Invention] Image forming apparatus

[Scope of Claims for Patent]

[Claim 1] An image forming apparatus characterized by a discomfort index, S, which satisfies $S < -0.5$, wherein the discomfort index S is calculated with the equation, using a loudness value and a tonality value, both psychoacoustic parameters obtained from the sound from the image forming apparatus at a location apart 1 meter from an end of the image forming apparatus:

$$S = 0.3135 \times (\text{Loudness value}) + 3.4824\,B \times (\text{Tonality value}) - 3.1460 \qquad (-1 \leq S \leq 1)$$

[Claim 2] The image forming apparatus according to claim 1, comprising:

an image carrier; and

an AC bias charging unit that applies an AC bias to charge the image carrier,

wherein the AC bias has a frequency, f, which satisfies 200 Hz < f.

[Claim 3] The image forming apparatus according to claim 2, further comprising:

a charging sound reduction unit that reduces a charging sound caused during charging from the charging unit to the image carrier.

[Claim 4] The image forming apparatus according to claim 3,

wherein the charging sound reduction unit comprises an image carrier eigenfrequency shift unit that shifts the eigenfrequency of the image carrier to a frequency different from a frequency obtained by multiplying the frequency f of the AC bias by a natural number.

[Claim 5] The image forming apparatus according to claim 3,

wherein the charging sound reduction unit comprises a sound absorber provided inside the image carrier.

[Claim 6] The image forming apparatus according to claim 3,

wherein the charging sound reduction unit comprises a damper processing provided on the image carrier.

[Claim 7] The image forming apparatus according to claim 1, comprising:

the image carrier; and

a DC bias charging unit that charges the image carrier using a DC bias.

[Claim 8] The image forming apparatus according to any one of claims 1 to 7,

wherein the discomfort index, S, satisfies S < -0.7.

[Claim 9] The image forming apparatus according to any one of claims 1 to 7,

wherein the loudness value and the tonality value are obtained from analysis executed by the acoustic analyzer BAS, after the running sounds from the image forming apparatus is collected by a dummy head, HMS (head Measurement System) III, both available from Head Acoustics Inc.

[Claim 10] The image forming apparatus according to claim 9,

wherein the discomfort index, S, satisfies S < -0.7.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to an image forming apparatus, more particularly, it relates to a method of reducing uncomfortable sounds, such as motor driving sounds, actuation sounds from clutches and solenoids, charging sounds,

and paper conveying sounds, and paper feeding sounds, from image forming apparatus, such as xerographic copiers and laser printers, which cause noises during their operations. It also relates to a technology applicable to OA machines in general.

[0002]

[Prior Art]

In recent years, the viewpoint of friendliness to the environment raises concerns on noise problems higher and increases needs to solving the noise problem even for OA machines in offices. Accordingly, sound reduction of OA machines has been intended and actually such the sound reduction has been advanced more than before.

[0003]

There are several technologies disclosed to solve such the noise problems. For example, JP 9-193506A publication discloses a technology using a noise-masking device which reduces discomfort of noises from a laser beam printer or a copier. The noise-masking device comprises a sound generator which generates a masking sound to mask noises from a drive mechanism that serves on operation as a noise source. The device also comprises a masking sound controller unit which controls and allows the sound generator to generate the masking sound having frequencies within a range that contains major component frequencies of the noises.

[0004]

However, the technology disclosed in the JP 9-193506A publication has a disadvantage because it adds the masking sound to noisy sounds caused functionally from the body without reducing the noisy sounds, resulting in an elevated noise level. Therefore, some persons may feel rather noisy and more uncomfortable. In addition, the technology requires the use of the sound generator which generates the

masking sound and the controller which controls the masking sound to be generated for a limited time period, during which the sounds to be masked are caused. Therefore, the technology also has a disadvantage because it requires, on layout of the machine, an extra space and greatly elevated cost.

[0005]

Currently, an acoustic power level (ISO 7779) is generally employed in OA machines as an approach which evaluates a noise. The acoustic power level is a value of acoustic energy produced from an office machine such as a copier and a printer. Accordingly, there may be often no well correlation between the acoustic power level and a human subjective discomfort against the noise. For example, when sounds with the same acoustic power level are heard and compared with each other, a difference in discomfort between them may be found. In addition, even if a sound has a low acoustic power level, a person may feel the sound extremely uncomfortable.

[0006]

Accordingly, a further improvement on the office environment requires reduction of the acoustic power level of an OA machine as well as progression in improvement on its sound quality. The improvement on the sound quality requires a quantitative measurement of the sound quality to grasp the current situation and a measurement of an improved degree after the improvement. However, the sound quality is not a physical quantity and accordingly can not be measured quantitatively.

When sounds are listened to through ears to compare their qualities with each other, a difference may occur in evaluations according to persons. In addition, an expression can be performed only qualitatively such that "the

sound quality was improved a little" or "considerably improved". Unless a quality of a sound can be expressed quantitatively with a physical quantity, even if measures are implemented for improvement on the sound quality, it is impossible to evaluate the effect objectively.

[0007]

Psychoacoustic parameters are physical quantities employed for evaluating sound quality. Typically, the psychoacoustic parameters include the following (see, for example, The Japan Society of Mechanical Engineering, The 7th Design and Systems Conference, "Direct to innovative leaps in design and systems towards the 21st century!", November 10 to 11, 1997, "Sounds/vibrations and design, colors and design (1)" division, 089B. Characters in brackets denote a unit).

- Loudness (sone), Magnitude of audibility
- Sharpness (acum), Relatively distributed quantity of high-frequency components
- Tonality (tu), Contents of pure components
- Roughness (asper), Roughness of sound
- Fluctuation strength (vacil), Humming

[0008]

The above parameters have a trend to indicate an increase in discomfort as either of them increases a quality. Among those, only the loudness is standardized in ISO 532B. As for other psychoacoustic parameters, the same fundamental concept can be applied, however, programs and computations are different from one another due to a unique research according to each measurement instrument maker. Therefore, measured values are slightly different from one another according to makers in common.

It is possible to improve the sound quality through an

effort for reducing all of these psychoacoustic parameters.

[0009]

[Problems to be Solved by the Invention]

However, it requires a great effort to prepare measures for all psychoacoustic parameters. Noises caused from OA machines such as copiers and printers are composed of many toned noises due to complexity of their mechanisms. For example, low-frequency heavy sounds, high-frequency screeching sounds and impulsive sounds are caused variably with time from a plurality of sound sources such as motors, recording papers and solenoids.

[0010]

A person judges these sounds totally and decides whether he/she feels uncomfortable or not. In this case, the person can be considered to weight on a particular part that relates to the discomfort before the decision. In a word, there are psychoacoustic parameters that are greatly effect on the discomfort and psychoacoustic parameters that are less effect on the discomfort, which differ due to tones from machines. For example, in a printer that causes impulsive sounds many times at a high speed, the impulsive sounds are felt the most uncomfortable. On the contrary, in a desktop printer that causes relatively silent sounds at a low speed, as impulsive sounds are caused less, a charging sound caused on AC-charging is felt the most uncomfortable. Thus, uncomfortable parts differ case by case. Accordingly, the low-speed machine and the high-speed machine may have different parts that require improvements on the sound quality. From such the ground, by searching psychoacoustic parameters that have great improvement effects on discomfort and improving the psychoacoustic parameters to improve sound quality efficiently, the above effort can be reduced.

[0011]

Accordingly, by combining psychoacoustic parameters that have great improvement effects on discomfort, then weighting the psychoacoustic parameters to derive a sound quality evaluative equation, and computing a subjective evaluation value against the discomfort using the sound quality evaluative equation, it is possible to evaluate the sound quality objectively and improve the sound quality. Further, by deciding, for a subjective evaluation value against discomfort, a degree that can eliminate the discomfort, and providing an image forming apparatus that has sound quality improved below the degree, it is possible to solve the noise-related problems in offices.

[0012]

An object of the present invention is, for the problem of discomfort sounds shown the above, to provide an image forming apparatus with a relieved psychological uncomfortable feeling. This can be achieved, in a relatively slow running image formation, by improving a charging sound. Concretely, an object of the present invention is, to provide an image forming apparatus with a relieved psychological uncomfortable feeling by the following ways.

(1) To improve a frequency component distribution of noises caused during operation,

(2) In the image forming apparatus with a charging system of a AC charging type, to improve a frequency component distribution of noises caused during operation,

[0013]

(3) In the image forming apparatus with a charging system of a AC charging type, to reduce a charging sound caused during operation,

(4) To change an eigenfrequency of an image carrier,

(5) To insert a sound absorbent material into the image carrier,

(6) To provide a damper processing on the image carrier,

[0014]

(7) To change the charging system to the DC charging,

(8) To further improve the above (1) to (7),

(9) To limit conditions of psychoacoustic parameters, and

(10) To further improve the above (9).

[0015]

[Means to Solve the Problems]

The present invention according to claim 1, an image forming apparatus characterized by a discomfort index, S, which satisfies $S < -0.5$, wherein the discomfort index S is calculated with the equation, using a loudness value and a tonality value, both psychoacoustic parameters obtained from the sound from the image forming apparatus at a location apart 1 meter from an end of the image forming apparatus:

$$S = 0.3135 \times (\text{Loudness value}) + 3.4824 \times (\text{Tonality value}) - 3.1460 \qquad (-1 \leq S \leq 1)$$

[0016]

The present invention according to claim 2, in claim 1, the image forming apparatus includes an image carrier and an AC bias charging unit that applies an AC bias to charge the image carrier. The AC bias has a frequency, f, which satisfies $200\ \text{Hz} < f$.

[0017]

The present invention according to claim 3, in claim 2, the image forming apparatus further includes a charging sound reduction unit that reduces a charging sound caused during charging from the charging unit to the image carrier.

[0018]

The present invention according to claim 4, in claim 3, the charging sound reduction unit comprises an image

carrier eigenfrequency shift unit that shifts the eigenfrequency of the image carrier to a frequency different from a frequency obtained by multiplying the frequency f of the AC bias by a natural number.

[0019]

The present invention according to claim 5, in claim 5, the charging sound reduction unit comprises a sound absorber provided inside the image carrier.

[0020]

The present invention according to claim 6, in claim 3, the charging sound reduction unit comprises a damper processing provided on the image carrier.

[0021]

The present invention according to claim 7, in claim 1, the image forming apparatus includes the image carrier; and a DC bias charging unit that charges the image carrier using a DC bias.

[0022]

The present invention according to claim 8, in any one of claims 1 to 7, the discomfort index, S, satisfies S < -0.7.

[0023]

The present invention according to claim 9, in any one of claims 1 to 7, the loudness value and the tonality value are obtained from analysis executed by the acoustic analyzer BAS, after the running sounds from the image forming apparatus is collected by a dummy head, HMS (head Measurement System) III, both available from Head Acoustics Inc.

[0024]

The present invention according to claim 10, in claim 9, the discomfort index, S, satisfies S < -0.7.

[0025]

[Embodiments of the Invention]

Fig. 1 is a view of the essential part of an arrangement

for illustrating an example of an image forming apparatus embodying the present invention.

The image forming apparatus shown in Fig. 1 is provided with a paper conveying system that includes the main tray 4, the bank feed tray 5, the manual feed tray 6, the feed roller 10 and the resist rollers 11. A recording paper is conveyed from the paper conveying system to the eject tray 9 through the process cartridge 3 and via the fixing unit 7 and an eject roller 12. The image writing unit 8, located above the process cartridge 3, includes a LD unit, a polygon mirror, an fθ mirror (not shown) and so forth. In addition, there are provided the photosensitive drum 1, a drive motor for rotationally driving rollers, and a drive transmission system that includes solenoids and clutches (not shown).

In this configuration, at the time of forming images, driving sounds from the drive motor and the drive transmission system, operation sounds from the solenoids and clutches, paper conveying sounds and charging sounds.

[0026]

Fig. 2 is a cross-sectional view of the essential part for illustrating an example of the process cartridge 3 shown in Fig. 1.

Around the image carrier or photosensitive drum 1, the charging unit or charging roller 21, the developing unit or developing roller 22 and the cleaning unit or cleaning blade 23 are located. The toner 24 in the process cartridge 3 is agitated and conveyed to the developing roller 22 by the agitator 25 and the agitating rod 26. The toner 24 magnetically attached to the developing roller 22 is frictionally charged negative on passing over the developing blade 27. The negatively charged toner 24 is transferred to the photosensitive drum 1 in the presence of a bias voltage and is attracted onto an electrostatic latent image.

[0027]

When a recording paper, passed through the resist rollers 11, passes in between the photosensitive drum 1 and the transfer roller 2, a toner image on the photosensitive drum 1 is transferred therefrom to the recording paper due to positive charges on the transfer roller 2. Residual toner stayed on the photosensitive drum 1 is scraped off by the cleaning blade 23 and collected, as waste toner, in a tank located above the cleaning blade 23. Other parts than the transfer roller 2 are integrated in the process cartridge 3, which allows the user to replace it easily.

[0028]

Fig. 3 is a perspective view of the essential part for illustrating an example of the charging roller 21 shown in Figs. 1 and 2.

As shown in Figs. 2 and 3, the charging roller 21 is such a member that always contacts the photosensitive drum 1 and rotationally follows it with a frictional force so as to primarily charge the outer surface of the photosensitive drum 1 uniformly. As shown in Fig. 2, the charging roller 21 comprises a central shaft 21a and a charging part 21b concentrically formed around the shaft 21a. A bias voltage consisting of a DC voltage and an AC voltage superimposed thereon is applied to the charging roller 21, during a charging operation, from a high-voltage power supply via an electrode pad 31, a charging roller press spring 32 and a conductive bearing 33. The charging roller 21 can charge the photosensitive drum 1 uniformly to the same voltage as the DC component in the bias voltage. The AC component in the bias voltage serves to charge the photosensitive drum 1 from the charging roller 21 uniformly without variations.

[0029]

The following description is directed to a proper value

for a frequency of the AC component that does not produce variations in an image.

Generally, as the number of prints per minute (hereinafter referred to as "ppm") increases, the AC component is required to have a higher frequency. Specifically, if the number of copies per minute is equal to 16 ppm or more, it is desirable that the frequency of the AC component has a proper value of 1000 Hz or more. In the case of a machine with a less ppm than that in the above case, it is not required to set such a higher frequency as the above case.

[0030]

When the charging roller 21 is employed to contact and charge the photosensitive drum 1, attractive and repulsive forces act alternately between the surface of the charging roller 21 and the surface of the photosensitive drum 1 in general and cause vibrations on the charging roller 21. This is due to the AC component in the bias voltage. The vibrations of the charging roller 21 lead to a noisy, high-frequency vibrating sound (charging sound) on the charging roller 21 itself. In addition, the sound is transmitted to the photosensitive drum 1 and vibrates the photosensitive drum 1, resulting in noises. The charging sound generally includes a frequency of the AC component and its integer-multiplied harmonics. If the AC component has a fundamental frequency of 1000 Hz, charging sounds may be caused as the second harmonics 2000 Hz, the third harmonics 3000 Hz and so forth while the higher a degree of harmonics the lower a sound pressure level.

If an image forming apparatus causes vibrations, a frequency below 200 Hz appears as a banding on an image and a frequency equal to or more than 200 Hz can be well heard as a sound. Acoustically, the frequency below 200 Hz is not

very troublesome because an acoustic sensitivity worsens for such the frequency. Accordingly, with respect to the charging sound, it is sufficient to consider only the cases of the AC component that has frequencies equal to or more than 200 Hz at the time of charging.

[0031]

Fig. 4 is a graph for showing an example of a result from a frequency analysis to noises from the image forming apparatus. The graph shown in the figure is mainly purposed to examine a distribution of frequencies. Accordingly, a relative comparison between sound pressure levels at respective frequencies is meaningful while an absolute comparison between sound pressure levels is meaningless because accurate calibration is not performed. In the figure, abrupt peaks at 1 kHz and 2 kHz are called charging sounds as described earlier.

As shown in Fig. 4, the charging sound has a sound pressure level higher by 10 dB or more than other surrounding frequencies. Such a high-level pure sound, though it has a very smaller amount energetically compared to the whole, can not be masked with other sounds and can be heard as an uncomfortable sound clearly.

[0032]

When a degree of discomfort is objectively evaluated on a mechanical sound, a standard for measuring the degree of discomfort is required. A noise meter is employed to evaluate energy of a sound. Similar to this case, it is required to measure some physical amounts of a sound, assigning the values of the physical amounts into a sound quality evaluative equation, and evaluating the degree of discomfort from the computed values.

[0033]

A sound quality evaluative equation predicting a degree

of discomfort of a sound is created by implementing experiment for subjective evaluation on humans and by performing a statistic analysis using plural psychoacoustic parameters. This sound quality evaluative equation must be statistically significant as high as 95% or more.

The psychoacoustic parameters used include the above-mentioned tonality, sharpness, roughness, fluctuation strength and so forth.

[0034]

Examples of tests for subjective evaluation on uncomfortable sounds implemented by the inventors are described. The subjective evaluation tests on uncomfortable sounds are implemented in the following procedures,

(1) Collection of running sounds from Image forming apparatus,

(2) Processing of the running sounds (Production of plural processed sounds (Sample sounds)),

(3) Measurement of psychoacoustic parameters from the produced sample sounds,

(4) Experiments on sample sounds by paired comparisons → Computation of subjective evaluation values against uncomfortable sounds, and

(5) Multiple regression analysis based on subjective evaluation values against uncomfortable sounds and measured values of psychoacoustic parameters → Derivation of a sound quality evaluative equation.

[0035]

(1) Collection of running sounds from Image forming apparatus,

To collect running sounds, three different types of image forming apparatus, A-machine (20 ppm), B-machine (16 ppm) and C-machine (16 ppm), were prepared. The running sounds from these three different image forming apparatus

were respectively collected by a dummy head, HMS (head Measurement System), available from Head Acoustics Inc., under the following measurement conditions and binaurally recorded through a digital audio tape (hereinafter referred to as DAT).

Thus recorded sounds can be reproduced through a special headphone that replays them feelingly as if a person actually listens to the mechanical sounds.

[0036]

[Measurement conditions]

• Recording environment, Semi-anechoic chamber (with a standard table)

• Location of ears in the dummy head, A height of 1.2 m and a horizontal distance of 1 m from a machine end

• Recording mode, FF (free field → for anechoic chamber)

• HP filter, 22 Hz

[0037]

(2) Processing of running sounds (Production of plural processed sounds (Sample sounds)),

A running sound from A-machine was processed using an acoustic analyzer, BAS (Binaural Analysis System), available from Head Acoustics Inc. Sample sounds 1 to 9 were produced using a method of processing running sounds, which removes from a recorded running sound a part, on a frequency axis or on a time axis, associated with each sound source in the image forming apparatus.

[0038]

(3) Measurement of psychoacoustic parameters in the produced sample sounds:

The sounds processed from the running sound from A-machine and the running sounds from B- and C- machines were subjected as sample sounds to measurement of psychoacoustic

parameter values using the acoustic analyzer, BAS, Head Acoustics Inc.

[0039]

(4) Experiments on sample sounds by Scheff's method of paired comparisons (Ura's modified method) → Computation of subjective evaluation values against uncomfortable sounds:

Subjects for evaluating sample sounds were gathered to compare paired sample sounds with each other and determine which one was felt uncomfortable. Ura's modified method is the following method of paired comparisons. Taking a comparison order into consideration, one subject compares all combinations once. Specifically, combinations each including two samples are created from t-pieces of samples, and N-subjects compare (i,j) with (j,i) in all combinations, thereby obtaining subjective evaluation values on sample sounds and determining their ranking. For example, in comparison of the sample sound 1 with the sample sound 2 (on a base of the sample sound 1), a subjective evaluation value on the sample sound 1 is calculated to get 1 point if the sample sound 1 is felt uncomfortable and -1 point if the sample sound 2 is felt uncomfortable. Results were totaled and statistically processed, resulting in a subjective evaluation value, α, obtained on each sample sound ($-1 \leq \alpha \leq 1$). The larger the subjective evaluation value α, the more the sound is felt uncomfortable. Table 1 shows the results. The sample sound 1 is an original sound of the A-machine.

[0040]

(Table 1)

SUBJECTIVE EVALUATION VALUES ON SAMPLE SOUNDS AND MEASURED VALUES OF PSYCHOACOUSTIC PARAMETERS

SAMPLE SOUND	SUBJECTIVE EVALUATION VALUE a	LOUDNESS (sone)	TONALITY (tu)	SHARPNESS (acum)	ROUGHNESS (asper)	FLUCTUATION STRENGTH (vacil)
1	-0.0968	8.1	0.13	2.4	0.8	1.01
2	0.6953	9.9	0.20	2.5	1.11	1.24
3	-0.7957	6.9	0.09	2.3	0.32	0.91
4	0.5627	10.3	0.15	2.4	1.24	1.12
5	0.2939	8.8	0.22	2.1	0.54	1.03
6	-0.0036	9.0	0.11	2.3	1.00	1.11
7	-0.3584	7.4	0.12	2.5	0.51	0.98
8	0.0609	8.0	0.21	2.5	0.63	0.99
9	-0.3584	8.0	0.08	2.7	0.96	1.12
B-MACHINE	-0.6604	7.4	0.06	2.6	0.61	1.31
C-MACHINE	-0.1957	7.7	0.21	2.7	0.61	1.25

[0041]

Among psychoacoustic parameters, only the loudness is standardized in ISO 532B. As for other psychoacoustic parameters, the same fundamental concept can be applied, however, programs and computations are different from one another due to a unique research according to each measurement instrument maker, it is not unusual that measured value may slightly vary when measured by measurement instruments of different makers. In this experiment, the dummy head HMS III and the acoustic analyzer BAS, both available from Head Acoustics Inc., were employed particularly.

[0042]

(5) Multiple regression analysis based on subjective evaluation values against uncomfortable sounds and measured values of psychoacoustic parameters:

A multiple regression analysis was performed to the subjective evaluation value and the values of psychoacoustic parameters, for deriving a sound quality evaluating formula which predicts the subjective evaluation values by the psychoacoustic parameters. As a result, it was found that the subjective evaluation value α can be predicted by a formula (a) which will be shown later.

The results were statistically in a 95% reliable zone. A contribution rate indicating accuracy of the formula was 97%. This means that the loudness and tonality contribute to 97% discomfort of a sound. The rest 3% discomfort is felt from other factors.

[0043]

The sound quality evaluative equation (a) yields a predicted value of the subjective evaluation value α, which is called a "discomfort index S". This discomfort index S has no unit.

The sound quality evaluative equation could predict sounds not from only A-machine but also B- and C- machines of different types. Accordingly, the equation can be held generally for a plurality of image forming apparatus (machines) with about 16 to 22 ppm.

$$\begin{aligned} S = {} & 0.3135 \times (\text{Loudness value}) \\ & + 3.4824 \times (\text{Tonality value}) \\ & + 3.1460 \qquad (-1 \leq S \leq 1) \ldots \quad (a) \end{aligned}$$

It was found that discomfort of noises from image forming apparatus of 16 to 22 ppm classes could be represented by the loudness (magnitude of audibility) and tonality

(content of pure sound components). It was also found that the charging sound was uncomfortable in the image forming apparatus having frequency components as shown in Fig. 4.

[0044]

Fig. 5 is a distribution view plotting relations between a subjective evaluation value α and a discomfort index S (a value predicted by the sound quality evaluative equation (b)).

As shown in the figure, there is a good correlation between the subjective evaluation value α resulted from a subjective evaluation experiment on human and the discomfort index S. The use of the sound quality evaluative equation (b) allows the sound quality to be evaluated on discomfort objectively.

[0045]

Table 2, mentioned later, collectively shows results from experiments on the discomfort index S, which indicate a certain degree of the discomfort index S that is required to eliminate discomfort.

Subjects are directed to hearing of the sample sounds 1 to 17 obtained by processing the running sound from A-machine and of the running sounds from B- and C- machines to evaluate them on discomfort in three stages. In Table 3, the mark "o" indicates a sound evaluated good, "x" a sound evaluated bad, and "Δ" a sound evaluated medium.

[0046]

In accordance with the results in Table 2, if a condition, $S < -0.5$ ... (c), can be satisfied, an uncomfortable feeling is relieved. Determination of the loudness and tonality values in the sound quality evaluative equation (b) so as to satisfy the condition (c) can provide an image forming apparatus that has a relieved uncomfortable

feeling.

If a condition, S < -0.7 ... (d), can be satisfied, it is possible to provide an image forming apparatus that causes a sound with discomfort hardly felt.

[0047]

(Table 2)

RESULT OF ABSOLUTE VALUATION OF SOUNDS

SAMPLE SOUND	S-VALUE	EVALUATION
2	0.639	×
4	0.588	×
5	0.362	×
10	0.346	×
13	0.182	×
12	0.177	×
8	0.060	Δ
6	0.059	Δ
C-MACHINE	-0.001	Δ
14	-0.075	Δ
16	-0.089	Δ
1	-0.187	Δ
17	-0.347	Δ
9	-0.392	Δ
15	-0.408	Δ
7	-0.426	Δ
11	-0.614	○
B-MACHINE	-0.617	○
3	-0.702	○

[0048]

The following is a process to reduce the charging sounds.

(1) The following content corresponds to the invention according to claim 4.

If vibrations caused between the charging roller 21 and the photosensitive drum 1 have a frequency that is coincident with or in the vicinity of a frequency obtained by multiplying the eigenfrequency fd of the photosensitive drum 1 itself by a natural number, the photosensitive drum 1 establishes resonance. This resonance leads to a sharp increase in a sound pressure level of the charging sound, resulting in a sharp elevation in the discomfort index S.

If the eigenfrequency fd of the photosensitive drum 1 is previously set to a frequency different from a frequency obtained by multiplying an AC-bias frequency f on charging by a natural number, the condition can be prevented. For instance, in the example shown in Fig. 4, a frequency obtained by multiplying 1000 Hz by a natural number is selected so as not to be coincident with the eigenfrequency fd of the photosensitive drum 1.

[0049]

Fig. 6 is a cross-sectional view of the essential part for illustrating an embodiment to shift the eigenfrequency of a photosensitive drum.

High-stiffness cylindrical members 41 are press-fitted in the photosensitive drum 1. When the cylindrical members 41 are press-fitted, the photosensitive drum 1 increases its weight and stiffness and, accordingly changes its eigenfrequency. As a result, uncomfortable charging sounds due to the resonance can be avoided even if the photosensitive drum 1 have an eigenfrequency fd that is coincident with or in the vicinity of a frequency obtained by multiplying an

AC-bias frequency f by a natural number. Because the eigenfrequency fd of the photosensitive drum 1 can be changed.

[0050]

(2) The following content corresponds to the invention according to claim 5.

Fig. 7 is a cross-sectional view of the essential part for illustrating another embodiment to shift the eigenfrequency of a photosensitive drum. Fig. 7(A) is a cross-sectional view of the photosensitive drum 1, into which a sound absorber 42 is press-fitted. Fig. 7(B) is a cross-sectional side view of the sound absorber 42 and the photosensitive drum 1.

As shown in Fig. 7(B), a columnar sound absorber 42 is prepared. It has a diameter, 2R, a size larger than the inner diameter, 2r, of the photosensitive drum 1. If the sound absorber 42 is composed of foamed polyurethane, it is convenient for handling. For example, a sound absorbent material, HAMA-DAMPER HU-4, available from Yokohama Rubber may be employed. This material can be elastically deformed and inserted into the photosensitive drum 1. Fig. 7(A) shows the sound absorber 42 in a state press-fitted into the photosensitive drum 1. The inserted sound absorber 42 expands and intends to return to the original shape not yet deformed and accordingly it is fixed in the photosensitive drum 1. The sound absorber 42 is not secured using an adhesive and the like and can be removed easily from the photosensitive drum 1. Thus, the charging sounds caused from the photosensitive drum 1 can be absorbed.

[0051]

(3) The following content corresponds to the invention according to claim 6.

Fig. 8 is a cross-sectional view of the essential part for illustrating a further embodiment to shift the

eigenfrequency of a photosensitive drum, showing the damper 43 in a state adhered onto the photosensitive drum 1.

The damper 43 absorbs energy from the vibrating photosensitive drum 1 and converts it into thermal energy. This is effective to attenuate a vibration rate or amplitude to reduce acoustic radiation. For example, a lightweight damping material, REGETLEX, available from Nitto Denko may be employed. This material is composed of a thin aluminum substrate and a high viscous adhesive attached thereon for absorbing vibration energy. Thus, the vibration energy, generated between the charging roller 2 and the photosensitive drum 1, due to the AC bias frequency f on charging, can be absorbed so as to prevent charging sounds from occurring.

[0052]

(4) The following content corresponds to the invention according to claim 7.

Fig. 9 is a cross-sectional view of the essential part for illustrating an embodiment of the process cartridge 8 with a charging system of a DC charging type.

Around the image carrier or photosensitive drum 1, the charging unit or charging roller 21 for applying a DC bias to the photosensitive drum 1, the developing unit or developing roller 22, the cleaning unit or cleaning blade 23 and a charge eraser lamp 28 are located. The toner 24 in the process cartridge 3 is agitated and conveyed to the developing roller 22 by the agitator 25 and the agitating rod 26. The toner 24 magnetically attached to the developing roller 22 is frictionally charged negative on passing over the developing blade 27. The negatively charged toner 24 is transferred to the photosensitive drum 1 in the presence of a bias voltage and is attracted onto an electrostatic latent image.

[0053]

When a recording paper, passed through the resist rollers 11, passes in between the photosensitive drum 1 and the transfer roller 2, a toner image on the photosensitive drum 1 is transferred therefrom to the recording paper due to positive charges on the transfer roller 2. Residual toner stayed on the photosensitive drum 1 is scraped off by the cleaning blade 23 and collected, as waste toner, in a tank located above the cleaning blade 23. Charge erasing is performed by the full illumination from LED to eliminate the residual potential on the photosensitive drum 1, preparing the next image formation. Other parts than the transfer roller 2 are integrated in the process cartridge 3, which allows the user to replace it easily.

[0054]

When an AC bias is employed for charging, due to an AC component in the bias voltage, attractive and repulsive forces act alternately between the surface of the charging roller 21 and the surface of the photosensitive drum 1 in general and may cause vibrations on the charging roller 21. On the contrary, when the DC bias is used for charging, vibrations can not occur on the charging roller 21 and thus charging sounds can not be caused. If only the DC bias is applied on the charging roller 21, a charge eraser unit which erases residual charges is required while it is not required in the AC charging. Thus, it is possible to prevent occurrence of uncomfortable charging sounds by changing the charging system from the AC charging to the DC charging.

[0055]

[Effects due to the Invention]

(1) Effect due to the invention according to claims 1 and 9

It is possible to relieve the uncomfortable feeling caused from noises occurred from the image forming apparatus.

[0056]

(2) Effect due to the invention according to claim 2

It is possible to relieve the uncomfortable feeling caused from noises occurred from the image forming apparatus charging with the AC bias.

[0057]

(3) Effect due to the invention according to claims 3, 4, 5, and 6

In the image forming apparatus employing for charging by the AC bias, it is possible to relieve the uncomfortable feeling caused from noises due to reduce the charging sound.

[0058]

(4) Effect due to the invention according to claim 7

It is possible to relieve the uncomfortable feeling caused from noises occurred from the image forming apparatus due to charge the charging unit using the AC bias.

[0059]

(5) Effect due to the invention according to claim 8

It is possible to relieve the uncomfortable feeling caused from noises occurred from the image forming apparatus for effects due to the inventions according to claims 1 to 7.

[0060]

(6) Effect due to the invention according to claim 10

It is possible to relieve the uncomfortable feeling caused from noises occurred from the image forming apparatus for effects due to the inventions according to claim 9.

[Brief Description of the Drawings]

[Fig. 1] Fig. 1 is a view of the essential part in an arrangement for illustrating an example of an image forming apparatus according to a first embodiment.

[Fig. 2] Fig. 2 is a cross-sectional view of the essential part for illustrating an example of a process

cartridge shown in Fig. 1.

[Fig. 3] Fig. 3 is a perspective view of the essential part for illustrating an example of a charging roller shown in Figs. 1 and 2.

[Fig. 4] Fig. 4 is a graph for showing an example of a result from a frequency analysis to noises from the image forming apparatus.

[Fig. 5] Fig. 5 is a distribution view which plots relations between a subjective evaluation value α and a discomfort index S (a predicted value by a sound quality evaluative equation).

[Fig. 6] Fig. 6 is a cross-sectional view of the essential part for illustrating an embodiment to shift the eigenfrequency of a photosensitive drum.

[Fig. 7] Fig. 7 is a cross-sectional view of the essential part for illustrating another embodiment to shift the eigenfrequency of a photosensitive drum.

[Fig. 8] Fig. 8 is a cross-sectional view of the essential part for illustrating another embodiment to shift the eigenfrequency of a photosensitive drum.

[Fig. 9] Fig. 9 is a cross-sectional view of the essential part for illustrating an embodiment of a process cartridge with a charging system of a DC charging type.

[Description of Signs]

1 photosensitive drum, 3 process cartridge, 4 main tray, 5 bank feed tray, 6 manual feed tray, 7 fixing unit, 8 writing unit, 9 eject tray, 10 feed roller, 11 resist roller, 12 eject roller, 21 charging roller, 21a central shaft, 21b charging part, 22 developing roller, 23 cleaning blade, 24 toner, 25 agitator, 26 agitating rod, 27 developing blade, 28 charge eraser lamp, 31 electrode pad, 32 charging roller press spring, 33 conductive bearing, 41 cylindrical member, 42 sound absorber, 43 damper

[Type of Document] Drawings

[Type of Document] Abstract

[Abstract]

[Object] To provide an image forming apparatus with a relieved psychological uncomfortable feeling. This can be achieved, in a relatively slow running image formation, by improving a charging sound. Concretely, an object of the present invention is, to provide an image forming apparatus with a relieved psychological uncomfortable feeling by the following ways.

[Means] A discomfort index, S, is calculated with an equation, $S = 0.3135 \times (\text{Loudness value}) + 3.4824 \times (\text{Tonality value}) - 3.1460$. This equation uses a loudness value and a tonality value, both psychoacoustic parameters obtained from a sound from the image forming apparatus at a location 1m apart from an end of the image forming apparatus. A sound caused at the time of charging an image carrier is improved so that the discomfort index S satisfies $S < -0.5$.

[Selected Figure] Fig. 5

[TYPE OF DOCUMENT] DRAWING

FIG. 1

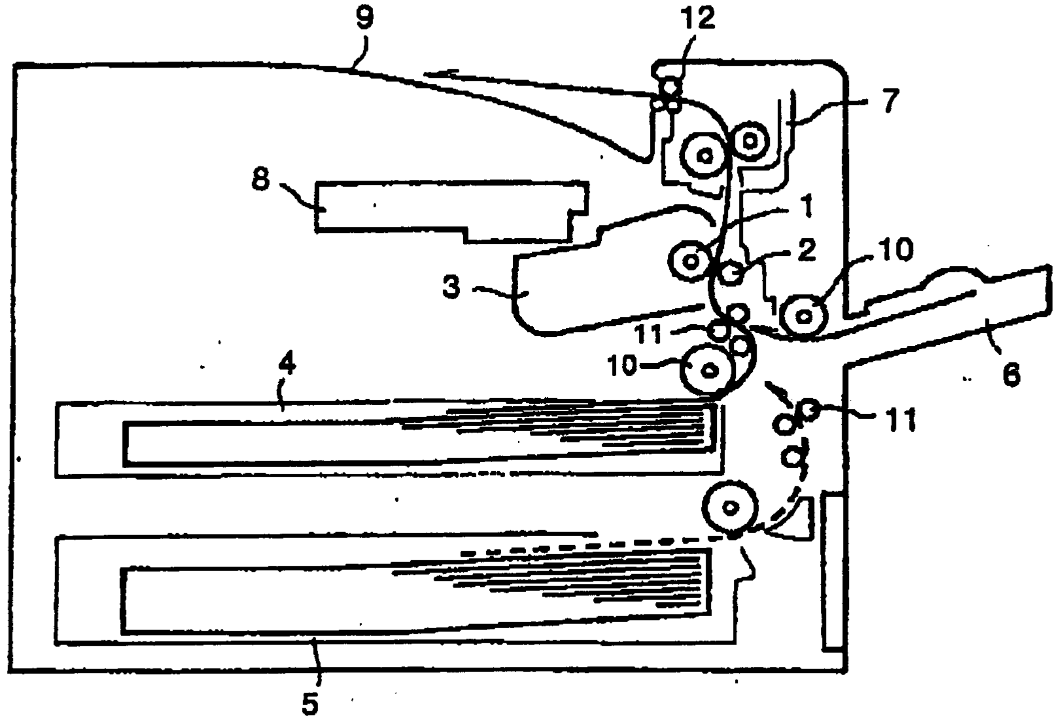


FIG. 2

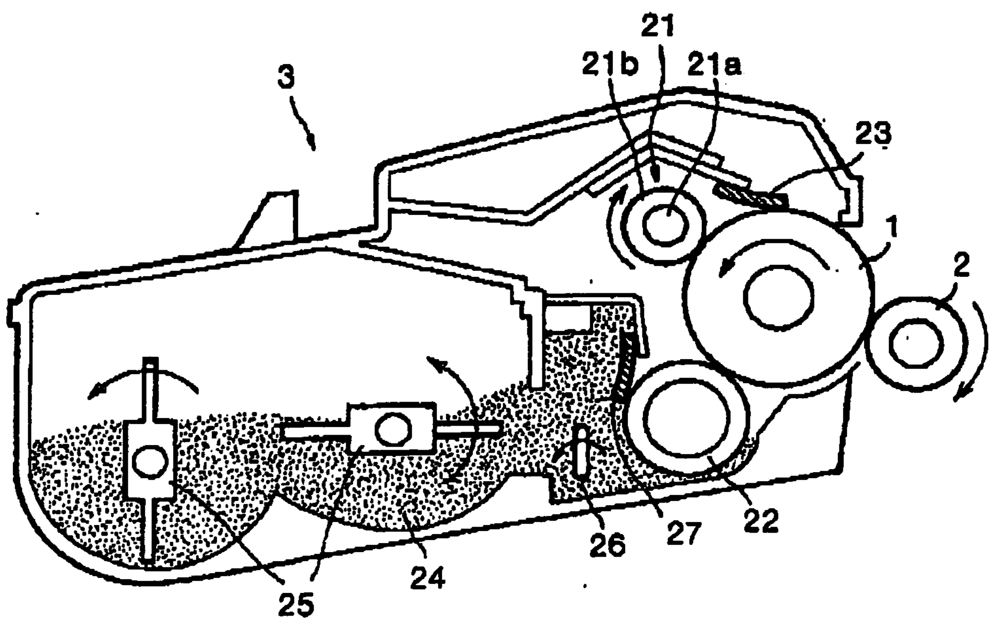


FIG. 3

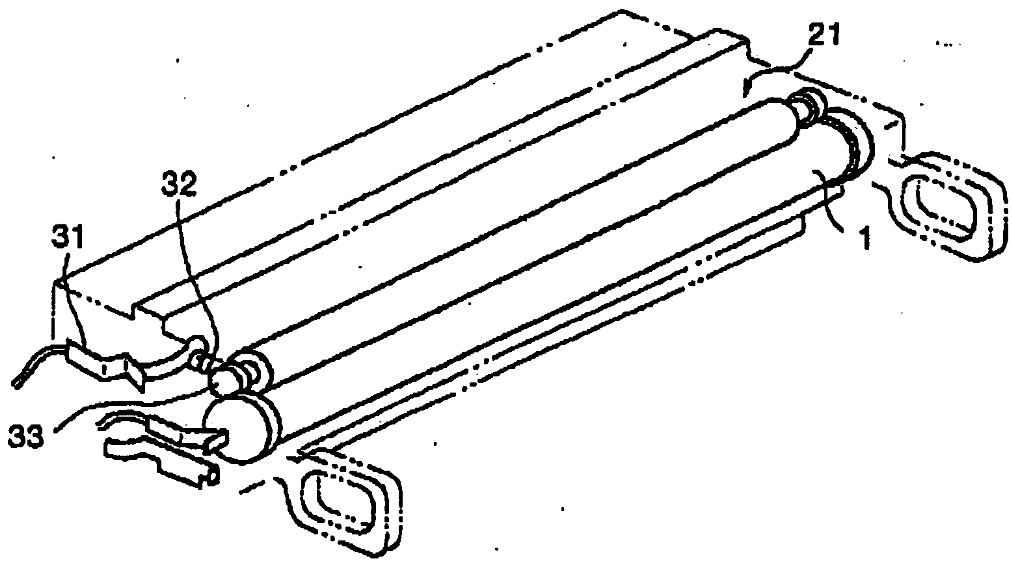


FIG. 4

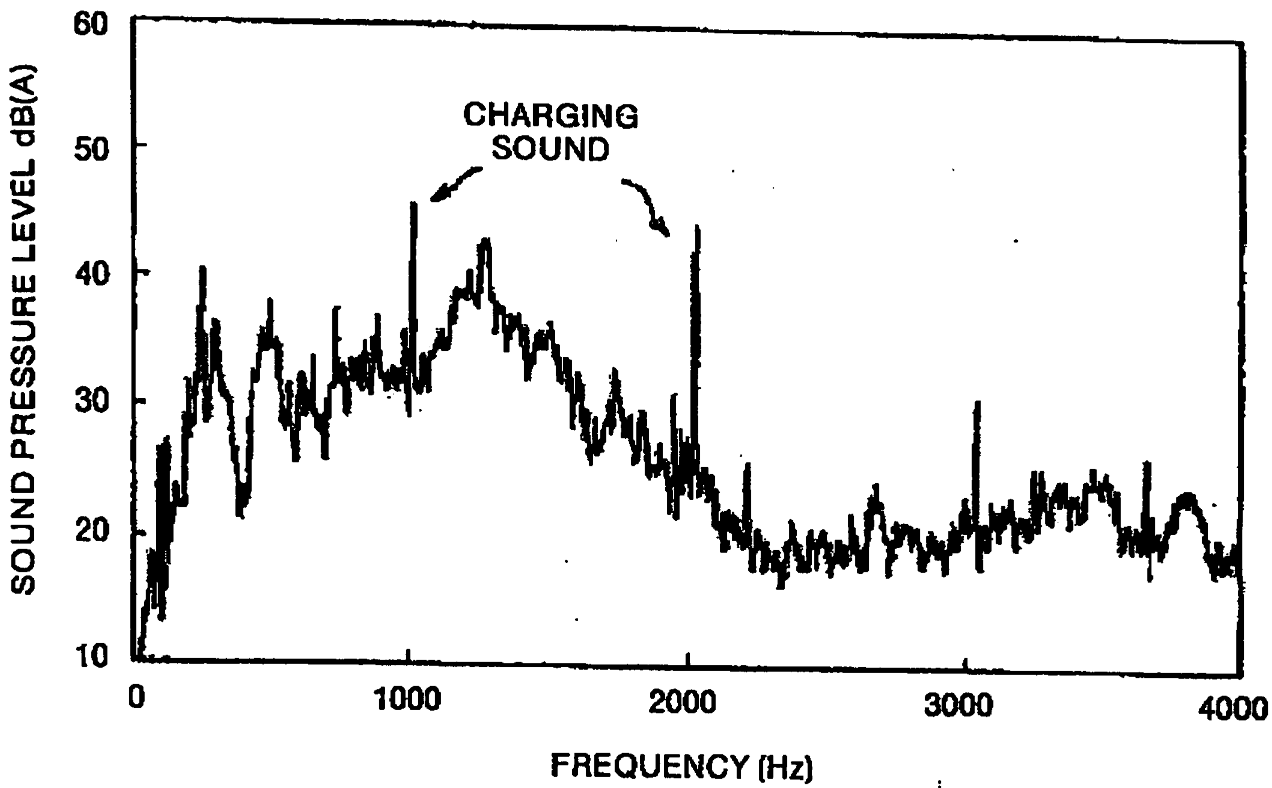

CHARGING SOUND
SOUND PRESSURE LEVEL dB(A)
60
50
40
30
20
10
0
1000
2000
3000
4000
FREQUENCY (Hz)

FIG. 5

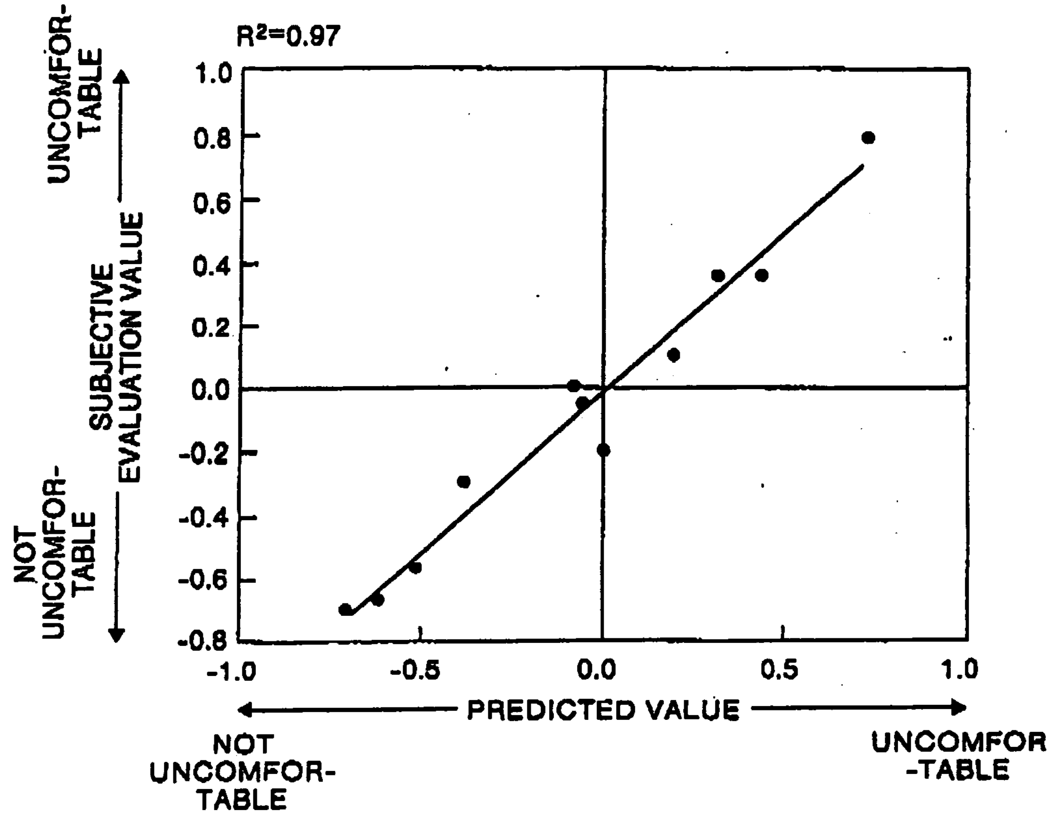

R²=0.97
UNCOMFOR-TABLE
SUBJECTIVE EVALUATION VALUE
NOT UNCOMFOR-TABLE
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-0.5
0.0
0.5
1.0
PREDICTED VALUE
NOT UNCOMFOR-TABLE
UNCOMFOR -TABLE

FIG. 6

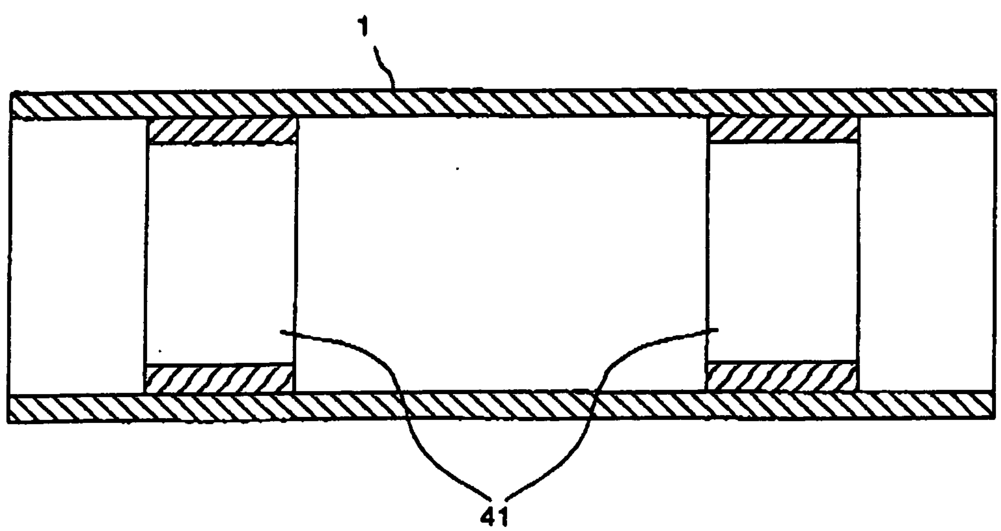
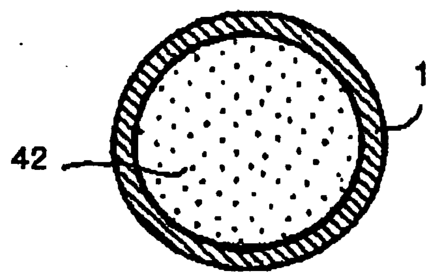

1
41

FIG. 7

(A)



(B)

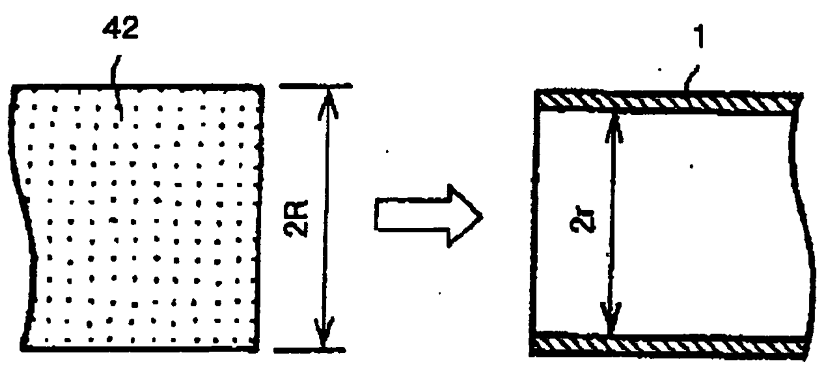


FIG. 8

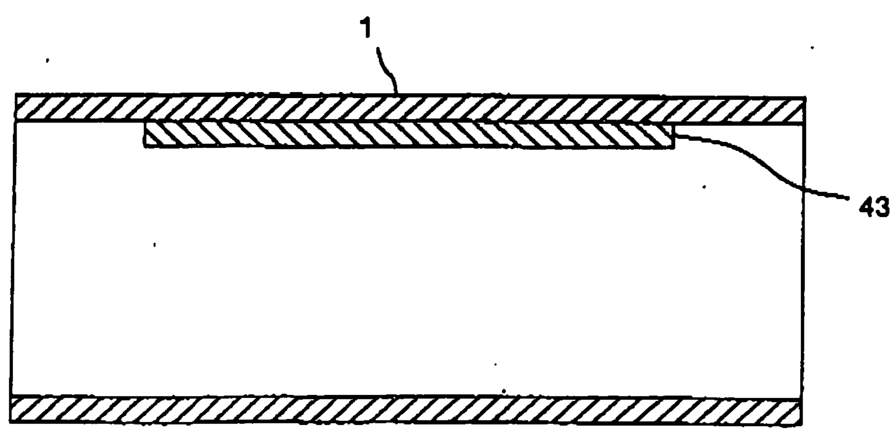


FIG. 9